

APPLICATION

FOR UNITED STATES LETTERS PATENT

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, **Donald D. Tilton**, a citizen of the United States, **Paul A. Knight**, a citizen of Canada, and **David H. Knaggs**, a citizen of the United States, have invented a new and useful liquid thermal management socket system of which the following is a specification:

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2
3 **Liquid Thermal Management Socket System**
4

5
6 **CROSS REFERENCE TO RELATED APPLICATIONS**

7 Not applicable to this application.
8
9

10 **STATEMENT REGARDING FEDERALLY**
11 **SPONSORED RESEARCH OR DEVELOPMENT**

12 Not applicable to this application.
13
14

15 **BACKGROUND OF THE INVENTION**
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17
18

19 **Field of the Invention**
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21 The present invention relates generally to thermal management systems for
22 electronic devices and more specifically it relates to a liquid thermal management
23 socket system for thermally managing an electronic device in a socket.
24
25

26 **Description of the Related Art**
27

28 Electronic devices removably positioned within sockets have been in use for
29 years. Sockets allow for efficient replacement and upgrading of electronic devices

1 (e.g. microprocessors). Figure 1b illustrates an exemplary socket unit (14) attached to
2 a circuit board (12) (e.g. motherboard, expansion board) that has a plurality of socket
3 receptacles (15) for receiving the device connectors of an electronic device. Figure 1a
4 illustrates an exemplary configuration of an electronic device (16) coupled to a socket
5 unit (14) with a heat sink (18) thermally coupled to the electronic device by a layer of
6 thermal interface material (17) to allow for air cooling of the electronic device.

7
8 While conventional “air cooling” of electronic devices, air cooling is not
9 desired an efficient method of thermally managing modern high-power electronics
10 which have high thermal management requirements. In addition, air cooling is
11 sometimes not capable of adequately thermally managing modern electronic devices
12 with high heat flux areas resulting in reduced efficiency and possibly failure of the
13 electronic device.

14
15 Liquid thermal management systems are the most promising technology for
16 thermally managing modern electronic devices. Liquid cold plates, liquid immersion
17 and spray cooling are the three most commonly utilized liquid thermal management
18 systems. Liquid immersion and spray cooling are typically more efficient than liquid
19 cold plates. Liquid immersion involves applying a dielectric liquid coolant directly over
20 one or more electronic devices. Spray cooling involves spraying a dielectric liquid coolant
21 onto one or more electronic devices. An exemplary spray cooling system is described in
22 U.S. Patent No. 5,420,804 to Tilton et al., and is hereby incorporated by reference.
23 Hence, it is desirable to utilize either liquid immersion or spray cooling in the thermal
24 management of modern electronic devices.

25
26 While liquid thermal management systems have significant performance
27 advantages over air cooled systems, there are some inherent problems. One of the
28 problems with conventional liquid thermal management systems is that they sometimes
29 require modifications by board manufacturers or electronic device manufacturers. A

1 further problem with conventional liquid thermal management systems is that they are
2 not easily integrated within the form factor of standard air cooled sockets. Another
3 problem with conventional liquid thermal management systems is that they do not have
4 an industry form factor as air cooled systems do.

5
6 In these respects, the liquid thermal management socket system according to the
7 present invention substantially departs from the conventional concepts and designs of
8 the prior art, and in so doing provides an apparatus primarily developed for the
9 purpose of thermally managing an electronic device in a socket.

1

2 **BRIEF SUMMARY OF THE INVENTION**

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4 In view of the foregoing disadvantages inherent in the known types of liquid
5 thermal management systems now present in the prior art, the present invention
6 provides a new liquid thermal management socket system construction wherein the
7 same can be utilized for thermally managing an electronic device in a socket.

8

9 The general purpose of the present invention, which will be described
10 subsequently in greater detail, is to provide a new liquid thermal management socket
11 system that has many of the advantages of the liquid thermal management systems
12 mentioned heretofore and many novel features that result in a new liquid thermal
13 management socket system which is not anticipated, rendered obvious, suggested, or
14 even implied by any of the prior art liquid thermal management systems, either alone
15 or in any combination thereof.

16

17 To attain this, the present invention generally comprises a thermal management
18 unit having a chamber for receiving one or more electronic devices, a plurality of first
19 connectors within the thermal management unit for electrically coupling with the
20 electronic device, and a plurality of second connectors electrically coupled to the first
21 connectors, wherein the second connectors extend from the thermal management unit
22 for electrically coupling within a socket unit on a board. The thermal management
23 unit may have a cap member attachable to a base portion in a sealed manner. The
24 chamber within the thermal management unit may thermally manage an electronic
25 device within via spray cooling, liquid immersion or other liquid cooling method.

26

27 There has thus been outlined, rather broadly, the more important features of the
28 invention in order that the detailed description thereof may be better understood, and
29 in order that the present contribution to the art may be better appreciated. There are

1 additional features of the invention that will be described hereinafter and that will form
2 the subject matter of the claims appended hereto.

3
4 In this respect, before explaining at least one embodiment of the invention in
5 detail, it is to be understood that the invention is not limited in its application to the
6 details of construction and to the arrangements of the components set forth in the
7 following description or illustrated in the drawings. The invention is capable of other
8 embodiments and of being practiced and carried out in various ways. Also, it is to be
9 understood that the phraseology and terminology employed herein are for the purpose
10 of the description and should not be regarded as limiting.

11
12 A primary object of the present invention is to provide a liquid thermal
13 management socket system that will overcome the shortcomings of the prior art
14 devices.

15
16 A second object is to provide a liquid thermal management socket system for
17 thermally managing an electronic device in a socket.

18
19 Another object is to provide a liquid thermal management socket system that
20 can be utilized within air cooled sockets.

21
22 An additional object is to provide a liquid thermal management socket system
23 that reduces the costs of utilizing liquid thermal management systems.

24
25 A further object is to provide a liquid thermal management socket system that
26 does not require any modifications to a board or a socket.

27
28 Another object is to provide a liquid thermal management socket system that
29 can be utilized with respect to various electronic device and socket coupler systems.

1
2 Other objects and advantages of the present invention will become obvious to the
3 reader and it is intended that these objects and advantages are within the scope of the
4 present invention.

5
6 To the accomplishment of the above and related objects, this invention may be
7 embodied in the form illustrated in the accompanying drawings, attention being called
8 to the fact, however, that the drawings are illustrative only, and that changes may be
9 made in the specific construction illustrated and described within the scope of the
10 appended claims.

1
2 **BRIEF DESCRIPTION OF THE DRAWINGS**
3

4 Various other objects, features and attendant advantages of the present
5 invention will become fully appreciated as the same becomes better understood when
6 considered in conjunction with the accompanying drawings, in which like reference
7 characters designate the same or similar parts throughout the several views, and
8 wherein:
9

10 FIG. 1a is a side view of a conventional socket unit with an electronic device
11 coupled to the socket unit along with a heat sink.
12

13 FIG. 1b is an upper perspective view of a conventional socket unit attached to a
14 circuit board.
15

16 FIG. 2 is an exploded upper perspective view of the present invention.
17

18 FIG. 3 is an exploded upper perspective view of the present invention with
19 respect to a socket unit.
20

21 FIG. 4 is an upper perspective view of the present invention coupled to a socket
22 unit (not seen) on a board.
23

24 FIG. 5 is a side view of the present invention coupled to a socket with an
25 electronic device contained within.
26

27 FIG. 6 is an exploded side view of the present invention with respect to a
28 socket unit.
29

1 FIG. 7 is a side cutaway view of the present invention utilized in a spray
2 cooling application.

3
4 FIG. 8 is a side cutaway view of the present invention utilized in a liquid
5 immersion application.

6
7 FIG. 9 is an upper perspective view of the base portion.

8
9 FIG. 10 is a side view of the base portion.

10
11 FIG. 11 is a side cutaway view of a device connector coupled within a first
12 connector of the base portion.

13
14 FIG. 12 is a perspective view of the inner portion of the cap member containing
15 a raised vapor management protrusion.

16
17 FIG. 13 is a perspective view of the inner portion of the cap member containing
18 a raised fluid management protrusion.

19
20 FIG. 14 is a perspective view of another embodiment of the present invention
21 wherein the base portion is directly mounted to the board.

22
23 FIG. 15 is a block diagram illustrating the fluid connection between the thermal
24 management unit and a liquid thermal management system.

DETAILED DESCRIPTION OF THE INVENTION

A. Overview

Turning now descriptively to the drawings, in which similar reference characters denote similar elements throughout the several views, FIGS. 3 through 15 illustrate a liquid thermal management socket system **10**, which comprises a thermal management unit **20** having a chamber **50** for receiving one or more electronic devices **16**, a plurality of first connectors **32** within the thermal management unit **20** for electrically coupling with the electronic device **16**, and a plurality of second connectors **34** electrically coupled to the first connectors **32**, wherein the second connectors **34** extend from the thermal management unit **20** for electrically coupling within a socket unit **14** on a board **12**. The thermal management unit **20** may have a cap member **40** attachable to a base portion **30** in a sealed manner. The chamber **50** within the thermal management unit **20** may thermally manage an electronic device **16** within via spray cooling, liquid immersion or other liquid cooling method.

B. Thermal Management Unit

The thermal management unit **20** has a chamber **50** capable of receiving one or more electronic devices **16** (e.g. semiconductor chips, microprocessors, integrated circuit devices, power conversion devices, laser diodes, memory devices, etc.) as shown in Figures 7 and 8 of the drawings. The chamber **50** is fluidly connected to a liquid thermal management system **60** where a liquid coolant is applied (spray form, liquid immersion, etc.) to the electronic device **16** for thermally managing the electronic device **16**. Thermal management of the electronic device **16** may include maintaining, lowering or increasing the temperature of the electronic device **16**.

The thermal management unit **20** may be comprised of various structures capable of receiving and thermally managing one or more electronic devices **16**. For

1 example, the thermal management unit **20** could be comprised of a structure with an
2 electronic device **16** permanently and non-removably positioned within the chamber
3 **50**.

4
5 Figures 2 through 8 illustrate the usage of a base portion **30** and a cap member
6 **40** removably attachable to the base portion **30**. The cap member **40** and the base
7 portion **30** together form the chamber **50** where the electronic device **16** is positioned
8 and thermally managed as shown in Figures 7 and 8 of the drawings. Additional
9 discussion regarding the base portion **30** and the cap member **40** is below. It can be
10 appreciated that various other structures may be utilized to construct the thermal
11 management unit **20** other than shown in the figures and that the scope of the present
12 invention should not be limited solely to the structure shown in the figures.

13
14 The thermal management unit **20** has a plurality of first connectors **32**
15 positioned within the chamber **50** of the thermal management unit **20** as best illustrated
16 in Figures 2, 3 and 9 of the drawings. The first connectors **32** may be electrically
17 coupled to device connectors **19** of an electronic device **16** as shown in Figure 11 of
18 the drawings. The first connectors **32** may be comprised of a pin grid array, a land grid
19 array or a ball grid array or other connection structure capable of electrically
20 communicating with an electronic device **16**.

21
22 The thermal management unit **20** has a plurality of second connectors **34** as best
23 illustrated in Figures 6 and 10 of the drawings. Each of the second connectors **34** are
24 electrically coupled to the first connectors **32** as best illustrated in Figure 11 of the
25 drawings. The second connectors **34** extend exteriorly of the thermal management unit
26 **20** for electrically coupling to at least one socket unit **14** or directly to a board **12**. The
27 second connectors **34** may be comprised of a pin grid array, a land grid array or a ball
28 grid array or other connection structure capable of electrically communicating with a
29 board **12**.

1
2 The second connectors **34** may correspond to the position of the first connectors
3 **32** as shown in Figure 11 of the drawings. As further shown in Figure 11 of the
4 drawings, the first connectors **32** may correspond to the position of the device
5 connectors **19** of the electronic device **16**.

6
7 **C. Base Portion**

8 The thermal management unit **20** may be comprised of a combination base
9 portion **30** and a cap member **40**. The base portion **30** comprises a floor **38** and a
10 sidewall **39** forming a cavity as best illustrated in Figures 7 and 8 of the drawings. The
11 cavity is sufficient in size and shape to receive at least one electronic device **16** as
12 illustrated in Figures 3, 7 and 8 of the drawings. The base portion **30** may have
13 various shapes and structures other than illustrated in the drawings.

14
15 A seal **36** is preferably positioned between the edge of the base portion **30** and
16 the edge of the cap member **40** for sealing the chamber **50** between thereof as shown in
17 Figures 7 and 8 of the drawings. Various seal **36** structures may be utilized to seal **36**
18 the cap member **40** to the base portion **30** as can be appreciated.

19
20 The first connectors **32** and the second connectors **34** may be attached within
21 the floor **38** as shown in Figure 11 of the drawings. The first connectors **32** and the
22 second connectors **34** are each correspondingly coupled together as further shown in
23 Figure 11.

24
25 Figures 2 and 9 illustrate the first connectors **32** as having a receptacle structure
26 in a pin grid array for receiving device connectors **19** comprised of a pin structure or
27 related structure. As stated previously, the first connectors **32** may also be comprised
28 of various other structures (e.g. raised structures, etc.) capable of usage in a ball grid
29 array, land grid array and other connection systems for electronic devices **16**. It can be

1 appreciated that the base portion 30 may include a retaining structure to retain the
2 electronic device 16 within the base portion 30 such as but not limited to levers,
3 fasteners and snaps.

4
5 Figures 6 and 10 of the drawings illustrate the second connectors 34 as having a
6 pin structure for electrically coupling within socket receptacles 15 of a socket unit 14.
7 As stated previously, the second connectors 34 may also be comprised of various other
8 structures (e.g. raised structures, etc.) capable of usage in a ball grid array, land grid
9 array and other connection systems for electronic devices 16.

10
11 Alternatively, the second connectors 34 may be electrically and physically
12 coupled to a board 12 similar to the connection between a conventional socket unit 14
13 and a board 12. Various connection methods may be utilized to connect the second
14 connectors 34 directly to the board 12 such as but not limited to pins soldered into the
15 board 12, ball grid arrays and land grid arrays.

16
17 ***D. Cap Member***

18 The cap member 40 is attachable in a sealed manner to the base portion 30 as
19 illustrated in Figures 7 and 8 of the drawings. The cap member 40 may have various
20 shapes and structures other than illustrated in the drawings.

21
22 The cap member 40 may be manufactured to dispense the liquid coolant
23 (dielectric or non-dielectric) in either a spray cooling or liquid immersion application.
24 Figures 7 and 12 illustrate utilizing the cap member 40 to dispense the liquid coolant
25 in a spray cooling thermal management method. One or more nozzles 43 are
26 positioned within the cap member 40 for spraying the coolant upon the electronic
27 device 16. The coolant may be atomized through the nozzles 43 as illustrated in U.S.
28 Patent No. 5,860,602 and U.S. Patent No. 6,016,969. The thermally conditioned liquid
29 coolant enters the inlet port 41 and is then dispensed into the chamber 50 upon the

1 electronic device 16 by the nozzles 43, thermally conditions the electronic device 16
2 through liquid immersion and then exits through the exit port as waste coolant to be
3 thermally conditioned by the liquid thermal management system 60. As shown in
4 Figure 12 of the drawings, a vapor management protrusion 46 may be utilized within
5 the cap member 40 to manage the vapor generated within the chamber 50. U.S. Patent
6 No. 5,220,804 illustrates a suitable vapor management protrusion 46. It can be
7 appreciated that the inlet port 41 and the outlet port 42 may be positioned in various
8 locations within the thermal management unit 20 such as also the base portion 30 and
9 any combination thereof.

10
11 Figures 8 and 13 illustrate utilizing the cap member 40 to dispense the liquid
12 coolant in a liquid immersion thermal management method. The thermally
13 conditioned liquid coolant enters the inlet port 41 into the chamber 50, thermally
14 conditions the electronic device 16 through liquid immersion and then exits through
15 the exit port. As shown in Figure 13, the cap member 40 may include a liquid
16 management protrusion 48 that directs the liquid coolant in a path that reduces
17 stagnation locations, such as a spiral pattern. It can be appreciated that the inlet port
18 41 and the outlet port 42 may be positioned in various locations within the thermal
19 management unit 20 such as also the base portion 30 and any combination thereof.

20
21 Figure 8 illustrates the usage of an encapsulant 44 between the electronic
22 device 16 and the base portion 30 to prevent a non-dielectric coolant from making
23 contact with the first connectors 32 and the device connectors 19. The encapsulant 44
24 can also be applied to surround and encase the first connectors 32 and the device
25 connectors 19 (not shown).

26 27 ***E. Liquid Thermal Management System***

28 The liquid thermal management system 60 is fluidly coupled to the chamber 50
29 for thermally managing an electronic device 16 by applying a liquid coolant to the

1 electronic device 16. The liquid coolant may be comprised of a dielectric or non-
2 dielectric depending upon the electronic device 16 being thermally managed. The
3 liquid thermal management system 60 may be comprised of spray cooling or liquid
4 immersion.

5
6 Applicant hereby incorporates by reference the following U.S. patents: U.S. Patent
7 No. 5,220,804 for a high heat flux evaporative cooling system; and U.S. Patent No.
8 5,860,602 and U.S. Patent No. 6,016,969, each for a laminated array of pressure swirl
9 atomizers. Although a laminated pressure swirl atomizer array is hereby incorporated by
10 reference, the present invention is not limited to such an apparatus, in fact, many
11 dispensing means are applicable to the present invention including but not limited to
12 inserted atomizers, jet orifices and incremental sprayers.

13
14 The liquid thermal management systems 60 described herein include a pump,
15 tubing, and the means for removing heat from a cooling fluid (e.g. heat exchanger). These
16 components are necessary for the operation of a liquid thermal management system 60 but
17 are widely understood in the field, and thus will not be covered in detail. Configurations
18 and details of the above components are not necessary for one skilled in the art to
19 understand the present invention.

20 21 ***F. Operation of Present Invention***

22 In use, the user may first electrically couple the thermal management unit 20
23 within one or more socket units 14 within a board 12 (or directly to the board 12) and
24 then position the electronic device 16 within the thermal management unit 20.
25 Alternatively, the electronic device 16 may be first positioned within the thermal
26 management unit 20 (sealed or non-sealed) and then later install the thermal
27 management unit 20 to the board 12 which does not require further explanation.

1 When electrically coupling the thermal management unit **20** to a socket unit **14**,
2 the user first aligns the second connectors **34** with the socket receptacles **15** of the
3 socket unit **14** as shown in Figure 3 of the drawings. The user then presses the thermal
4 management unit **20** so that the second connectors **34** are electrically coupled within
5 the socket receptacles **15** of the socket unit **14**.

6
7 After the thermal management unit **20** is properly seated upon the socket unit
8 **14**, the user then positions one or more electronic devices **16** directly above the first
9 connectors **32** so that the device connectors **19** correspond to the first connectors **32** as
10 shown in Figure 2 of the drawings. The user then presses the electronic device **16**
11 downwardly into the base portion **30** of the thermal management unit **20** so that the
12 device connectors **19** electrically couple with the first connectors **32** within the thermal
13 management unit **20**. Various mechanical devices may be secured to maintain the
14 electronic device **16** in the desired position. An encapsulant **44** may be added about
15 the electronic device **16** and/or first connectors **32** and device connectors **19** if desired.

16
17 The cap member **40** is then attached in a sealed manner to the base portion **30**
18 as shown in Figures 4 and 5 of the drawings. The thermal management unit **20** is then
19 fluidly connected to the liquid thermal management system **60** as shown in Figure 15
20 of the drawings.

21
22 The electronic device **16** may then be activated which generates heat (or heated
23 liquid coolant may be first applied to the electronic device **16** to achieve a desired
24 temperature). The electronic device **16** electrically communicates and is
25 communicated to through the electrical connection created between the respective
26 device connectors **19**, first connectors **32**, second connectors **34** and the socket
27 receptacles **15**.

1 The thermally conditioned liquid coolant is applied to the electronic device 16
2 within the chamber 50. After the liquid coolant is heated (or cooled) from the
3 electronic device 16, the waste coolant is then returned to the liquid thermal
4 management system 60 for thermal conditioning and cleaning. It can be appreciated
5 that the above method of use can be utilized in conjunction with pin grid arrays, ball
6 grid arrays, land grid arrays and other connection systems.

7
8 As to a further discussion of the manner of usage and operation of the present
9 invention, the same should be apparent from the above description. Accordingly, no
10 further discussion relating to the manner of usage and operation will be provided.

11
12 With respect to the above description then, it is to be realized that the optimum
13 dimensional relationships for the parts of the invention, to include variations in size,
14 materials, shape, form, function and manner of operation, assembly and use, are
15 deemed to be within the expertise of those skilled in the art, and all equivalent
16 structural variations and relationships to those illustrated in the drawings and
17 described in the specification are intended to be encompassed by the present invention.

18
19 Therefore, the foregoing is considered as illustrative only of the principles of
20 the invention. Further, since numerous modifications and changes will readily occur to
21 those skilled in the art, it is not desired to limit the invention to the exact construction
22 and operation shown and described, and accordingly, all suitable modifications and
23 equivalents may be resorted to, falling within the scope of the invention.